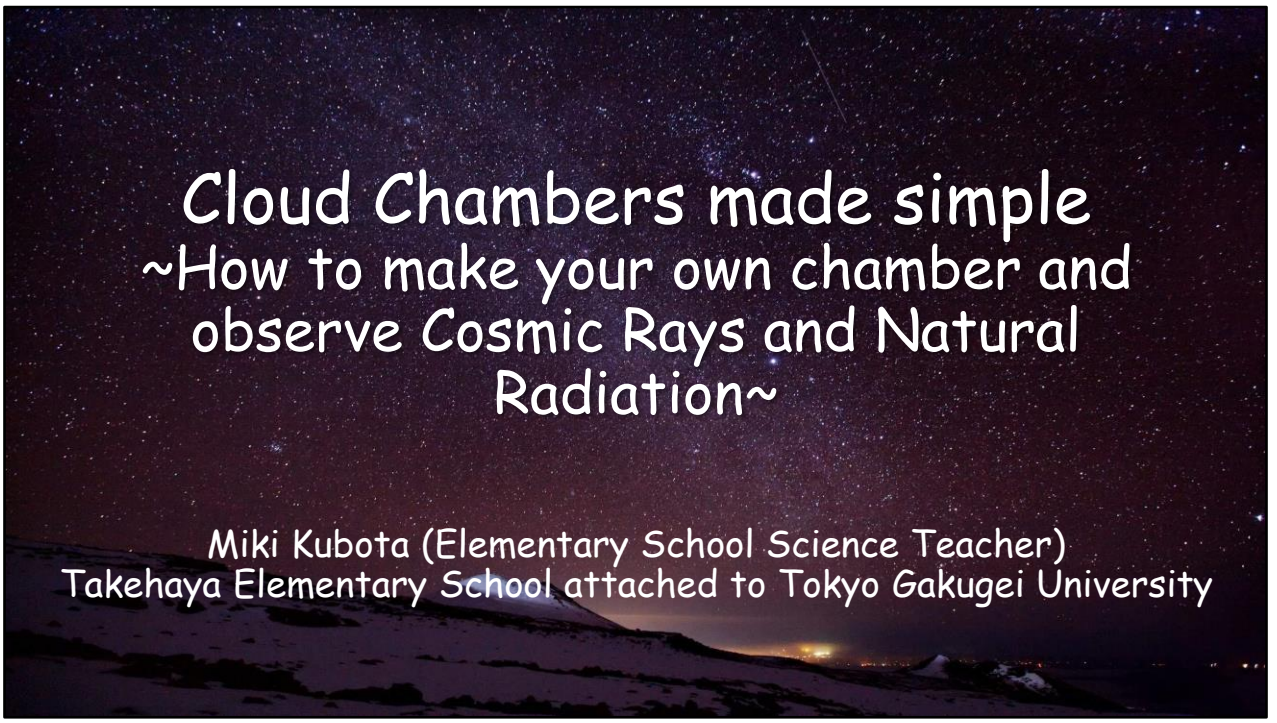


Hello, I am Miki Kubota from Takehaya Elementary School attached to Tokyo Gakugei University. Today I am connecting from JAXA Sagamihara Campus, and I've really been looking forward to meeting you at this workshop.

Today, I would like to introduce you how to make simple cloud chambers and use them to observe natural radiation and cosmic rays.

When You Hear "Radiation" or "Cosmic Ray," what impression do you get?

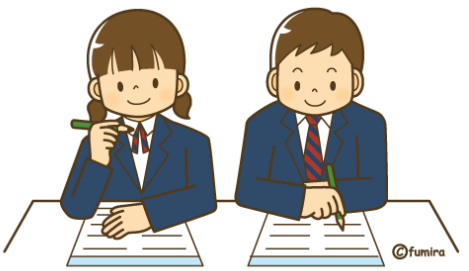
"There are a lot of them around us."

"I've never heard of them."

"I'm very interested in them."

"I'm afraid of them."

….. what's your opinion?



What is the first thing that comes into your mind when you hear the word "radiation" or "cosmic rays"?

Are you familiar with them? Or are you afraid of them? Let me ask- I'm very interested in what you think of these words.

Who are familiar with radiation and cosmic rays?

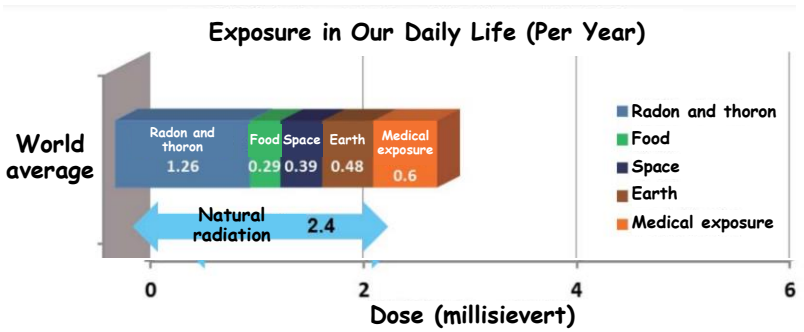
Who has never heard of these?

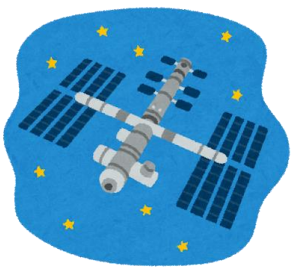
Who are not sure about these?

Who are afraid of these?

When junior high school students in Japan are asked this question, most of the students answer "I'm afraid of it" or "I don't really know about it". In fact, not only junior high school students but also adults, lot of people seem to feel the same way.

However, both radiation and cosmic rays are something that are very close to our daily lives.





We are constantly exposed to natural radiation and cosmic rays, just by living normal daily lives on Earth. And it's not just in some places on Earth, it's the same anywhere around the world.

On average globally, about 80% of the radiation we are exposed to in a year comes from nature, and about 16% of that comes from space, which are called cosmic rays. Of course, it comes from space, but the Earth's atmosphere blocks some of the cosmic rays coming to Earth, so those that reach the ground is a lot fewer than that in space. That means, the amount increases when you go higher, like when you get on an airplane or go into space. For example, suppose you travel from Tokyo to Houston, which we all had planned to in the first place. You fly high up in the sky, about 35000~40000ft. Then, you are closer to cosmic rays than on the ground, which makes you exposed to a greater amount of cosmic rays than on the ground. There is a website that you can calculate how much radiation doses you got when you travel on a plane, and according to that, doses you get during traveling from Tokyo to Houston calculates up to about 50.8 micro sievert. (which, you don't have to worry about health problems because of this)

And similarly, when you stay in space, you are exposed to more radiation than on the ground.

We are exposed to radiation from, for example, the following types of sources:

- Food and nature <Potassium (40 K)>
  Contained in food and humans and animals.
- Air <Radon>
- Soil and rock
  Western Japan has relatively higher radiation. Measured values are greater in tunnels or basements surrounded by soil.
- Outer space
  Radiation (cosmic rays) is also flying about in space. → It is blocked by the atmosphere before reaching the ground, but people in space are exposed to more cosmic rays than on the ground.

Astronauts can monitor their own exposure using detectors, and are managing radiation doses.

Radiation is not something special that comes from a certain special place. It is generated from various places and exists around our daily life. Here are some examples.

Potassium in plants and animals contains a certain percentage of a radioactive isotope called “Potassium-40.” Since it’s natural, things on Earth that contain potassium emit some radiation. This means that not only our food but also plants, their fertilizers, and we humans emit some radiation. This is, however, very natural, and they do not affect our health because of this.

Radon contained in the air also emits radiation. There are hot springs whose water contains radon, and many people use them.

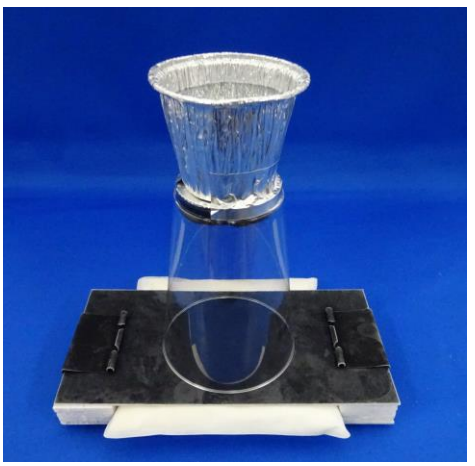
Since radiation is contained in rocks, when you are in a tunnel or underground, you are exposed to radiation emitted from the surrounding earth. The amount of radioactive materials in rocks or underground varies from place to place. That is also natural.

And as I explained earlier, radiation also exits in space. Radiation in space is also called “cosmic rays. A lot more cosmic rays are flying around in space than on the Earth’s surface. Some of these cosmic rays come toward Earth, but many of them are blocked by the atmosphere. Only part of them can be observed on the ground. When astronauts and the like conduct activities in space, they do so in an environment with more cosmic rays than on the ground.

Therefore, they monitor their exposure dose with detectors and manage the radiation they are exposed to.

We Can See Tracks of Radiation with a Cloud Chamber.

What you can see: Tracks of natural radiation, cosmic rays, and particles bounced off when cosmic rays hit the air (secondary cosmic rays)



Cosmic rays and radiation share the same character- they are all INVISIBLE. Since you can't see them, you don't know where they exist and how much radiation there is. Various methods and instruments have been developed to detect or measure them.

Although you can't see them, there are several ways to know that invisible radiation or cosmic rays "have passed through."

One of them is to use a machine that detects radiation and lets us know by displaying numbers or by beeping sound. When you use a "radiation detector" or "survey meter," you can measure how much radiation there is at any given place.

Using this method, you can know the "dose" of radiation.

The second method is to use an experimental device called a "cloud chamber" that indicates "where radiation have passed." The result is given to you not in values but as tracks that indicate when and where radiation passed. The picture to the right is the cloud chamber.

These methods are used differently depending on the situation. Today, I will show you how to make an easy cloud chamber, and how to observe natural radiation or cosmic rays!

THIS is where radiation have passed!

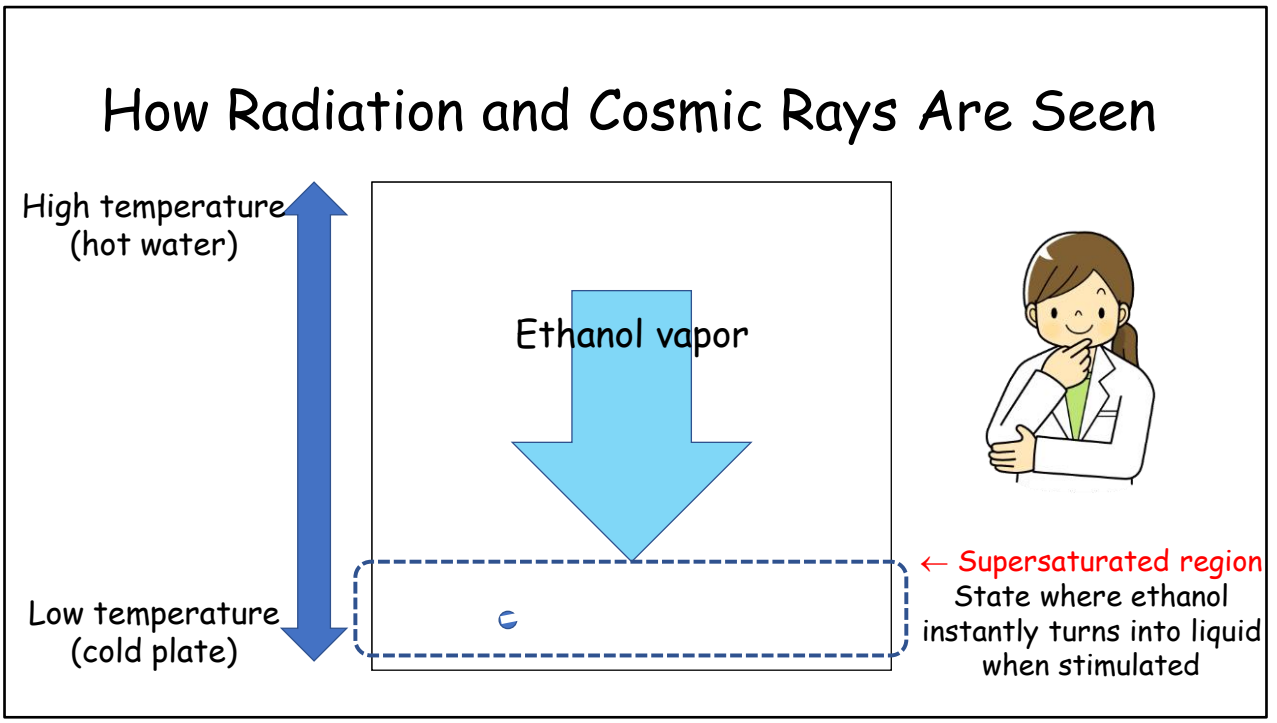
These tracks come from radioactive source in the middle.
But even if you put nothing in the chamber
it still shows tracks! That means…

The radiation tracks look like this in cloud chamber. In this picture, radiation emits from a cloth-like thing at the center. This is a mantle used for lanterns.

Once radiation is detected, a white contrail-like track appears. It only appears for a second and quickly disappears. One track appears per radiation ray, and from the direction it appears, we can tell that rays come from the center- the radioactive source.

Here, our purpose is to observe natural radiation or cosmic rays. So, we are not going to put anything in the center like the radiation emitting object found in this photo (radioactive substance that contains Thorium); we will try to observe the tracks we can see when there is nothing in there, because natural radiation and the cosmic rays come from outside the cloud chamber and pass through it.

When radiation itself passes in the cloud chamber, you can see a long track crossing the chamber. Other than that, secondary cosmic rays generated by cosmic rays hitting the atmosphere also appear as tracks like those generated by other natural radiation rays. We cannot precisely judge which tracks are for cosmic rays from space, but I am sure you will be able to vividly see the signs as tracks of radiation generated in nature.



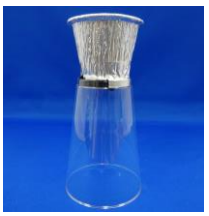
Now I will explain the mechanism of this cloud chamber that shows cosmic rays as tracks.

Cloud chamber is simply a box filled with ethanol vapor, and the bottom part is kept cold, and the top hot. This is what happens inside the chamber during the experiment.

Ethanol vapor, soaked in the felt at the top, fills inside of the cloud chamber. Temperature differences occur between the upper and lower part by providing a cold plate at the bottom of the chamber and hot water at the top. The temperature differences cause ethanol vapor to collect at the bottom, and less than an inch from the bottom of the chamber becomes a “supersaturated region” of ethanol vapor. A supersaturated region is an area under a state where ethanol vapor instantly becomes liquid once it is exposed to stimulation.

When ions generated by radiation or cosmic rays exist in this supersaturated region, ethanol vapor quickly aggregates and appears as a visible track.

Let's Make a Cloud Chamber!



[Materials for the cloud chamber]	Qt.
Transparent plastic cup (made of polystyrene); With a volume of about 14oz	1
Aluminum cup (strong enough to hold hot water) Its bottom should be the same size as the styrol cup.	1
Black felt (the same size as the bottom of the plastic cup)	3
Aluminum tape	some

Today I will show you how to make your own cloud chambers, using things that are very common- maybe you already have some of them at home!

You need the following to make the cloud chamber. A plastic cup made of styrene that is hard, transparent. One that has a design or has wavy or patterned sides, is not suitable.

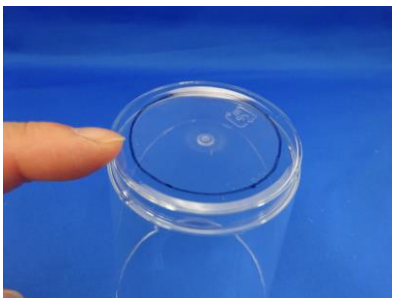
An aluminum cup that can be filled with hot water is needed. Choose a sturdy one that cannot be easily crushed with your hands. Cupcake molds work.

From this part of the presentation, I will actually show you the items and procedures on screen. So maybe switching to speaker mode and showing both me and the video might be better.

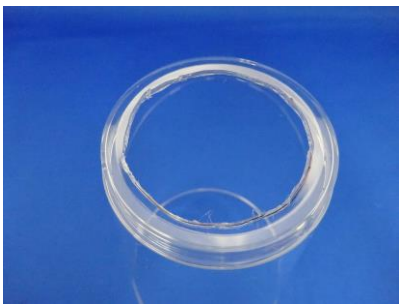
How to Make the Cloud Chamber

(1) Cut off the bottom of the plastic cup.

Heat cutter or a hot rod is useful



Be careful not to burn yourself!

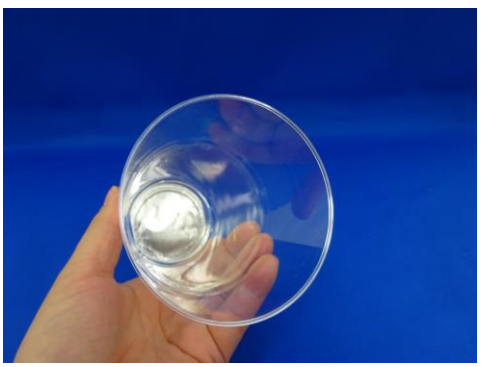


First, we will prepare the main body of the cloud chamber.

Cut the bottom of the plastic cup into a circle. Since the plastic cup is hard, you may need to use heat cutters and melt them through. Hot rod for soldering can be used, too. You need to cut off the bottom part leaving a little bit around so that you can apply aluminum tape there. Common plastic cups have a slight line at the bottom which can be used as a perfect guide for cutting off the bottom.

How to Make the Cloud Chamber

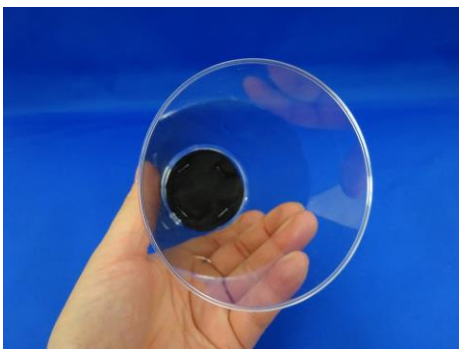
(2) Apply aluminum tape to the hole in the bottom from outside the cup.



Next, apply aluminum tape to the hole in the bottom from outside the cup. Some aluminum tape will stick out around the hole, and it's okay to fold it down to the side of the cup. But you can cut the tape into the same shape as the bottom of the cup for a beautiful finish. Since you apply the aluminum tape from outside, the inside of the cup will be sticky now.

How to Make the Cloud Chamber

(3) Staple three layers of felt and attach the felt to the aluminum tape from inside the cup.



Attach the felt to the bottom.

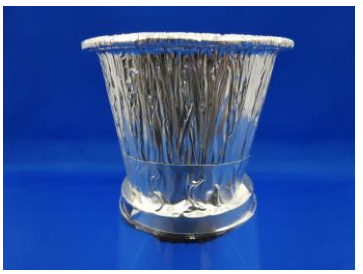
Stack three layers of felt cut into the same size as the bottom of the cup and staple them at about four places. Apply the felt layers from inside the cup to the sticky surface of the aluminum tape on the bottom. Press firmly from the both sides to secure it in place. Don’t just push it from the inside- the aluminum tape might tear!

How to Make the Cloud Chamber

(4) Place the aluminum cup so that its bottom matches the bottom of the plastic cup. Fix them in place with the remaining aluminum tape.

Aluminum cup

Aluminum tape



Place the aluminum cup so that its bottom matches the bottom of the plastic cup and fix it into place using some aluminum tape. Since you pour hot water into the aluminum cup, fix it firmly in place so that it does not fall off from the plastic cup. Spilling hot water might lead to burnt hands and disasters.

Now we are finished with the cloud chamber. This cloud chamber does not have a bottom. We use this cloud chamber on aluminum plate which I named "cold plate", and that plate serves as the bottom of the cloud chamber.

How to Make the Cloud Chamber

As long as it has

-clear sides

-upper container for hot water

-felt for soaking ethanol near the hot water

You can make it with various containers!

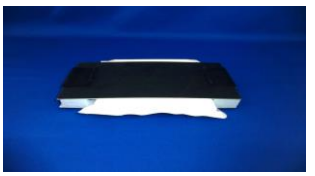
One with square plastic box

Top part of the plastic bottle with test tube for hot water

In fact, as I explained earlier, the important thing for this cloud chamber to work is to have a space filled with ethanol, so it doesn't necessarily have to be made with plastic cups. As long as you follow the principles of this cloud chamber, you can make it with various containers.

Next we will move on to making the Cold plate.

How to make a Cold Plate



[Material for the cold plate]	Qt.
Aluminum plate painted black on either side or both sides 7.8nches x 3.9inches, 0.6inches thick	2
Double clip about 2inches wide	2
Cold insulator (that can maintain about 0° F) Those contained in a plastic bag are suitable	1
Styrofoam block 0.8inches x 1inche x 4inches	2

Now we are going to make a cold plate, which is a cooling device. As we use an ice pack, it is reusable.

These are what we need to make a cold plate.

Two aluminum plates painted black on at least one side.

Two double clips that are extra large- about 2inches wide.

Two Styrofoam blocks that are about 7/10 inches square and 4inches long.

And lastly, a gel ice pack with a melting point of around 0 degrees Fahrenheit. You cannot use ice packs which are really just plastic bags that are simply filled with water or gelled water.

Actually this was the only thing I wasn't sure if it was available in the US. If not, you can substitute it with a Ziplock bag with some old towel inside it, and pouring saturated salt water in it.

How to Make the Cold Plate

(1) Place the gel ice pack (not frozen yet) at the center of the aluminum plate, and Styrofoam blocks at the each end of the aluminum plate.

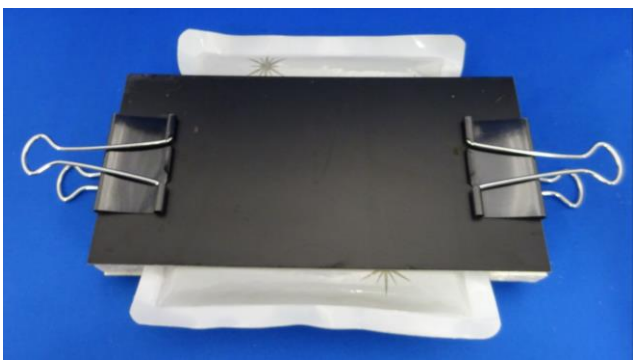
First, place the aluminum plate on the desk with its black side facing downward. You might want to use gloves, as the sides of the aluminum plates are sometimes rough.

Then place the ice pack at the center of the aluminum plate.

Since there will be leftover areas of the aluminum plate at both ends of the ice pack, place Styrofoam blocks that are as thick as the insulator on those ends. Make sure Styrofoam blocks don’t fall off the aluminum plate.

How to Make the Cold Plate

(2) Place another aluminum plate on it, sandwich the ice pack between the two plates, and pinch each end of the plate assembly with a double clip.

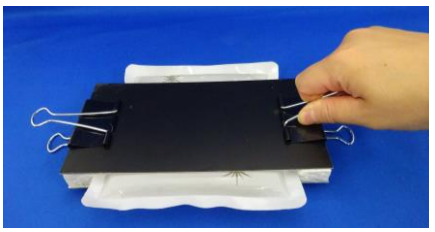


Place another aluminum plate on top of everything. Again, place it so that the black side of the aluminum plate faces outward.

When you look at this from the side, it looks like two aluminum plates sandwiching the ice pack and Styrofoam blocks. Then, clamp each of the shorter ends of the assembly with a double clip.

How to Make the Cold Plate

(4) Remove the handle of each double clip and freeze the assembly in the freezer after making sure that the gel ice pack is squeezed and does not fall out.



Squeeze and remove the handle of each double clip. Make sure that the ice pack stays where it is when turned over- if it comes out, you may have to cut the Styrofoam blocks a bit thinner and check again. If it's okay, the cold plate is ready to freeze!

Using a typical freezer, the cold plate should completely freeze after a full day or two in the freezer. This ice pack hardens when it freezes, so you can touch the sides of the ice packs to make sure it's frozen.

Once the cold plate is frozen, we can start the experiment.

If you can see a track without radioactive material inside, it is a track of natural radiation or cosmic rays!

Experimental Method

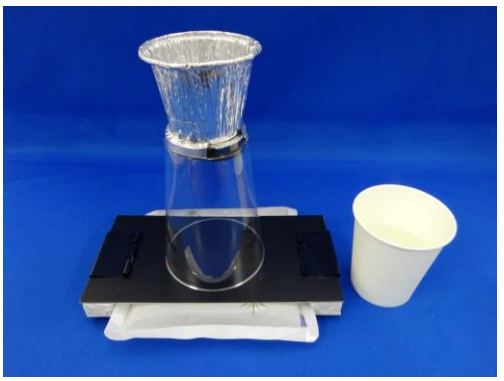
1. Turn the cloud chamber upside down and soak the black felt part in about 0.2oz of ethanol (70% or more).

Now I will show you how to observe radiation tracks using the cloud chamber.

Turn the cloud chamber upside down, and soak the felt inside the transparent plastic cup in ethanol. About 6 mL (0.2oz) of ethanol is sufficient.

Experimental Method

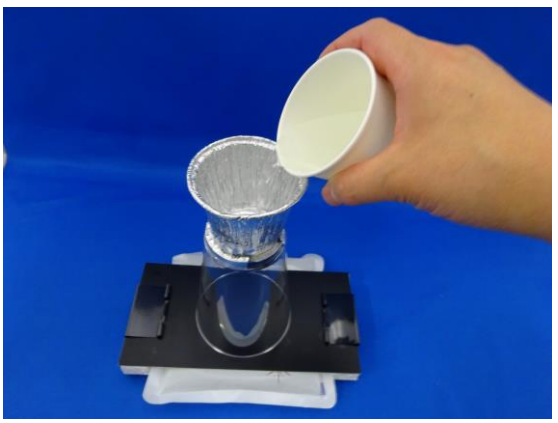
2. Place the cloud chamber at the center of the cold plate with its metallic part facing upward. (Ensure that the entire bottom of the cloud chamber rests on the cold plate.)



Place the plastic cup side of the cloud chamber on the cold plate. Now be sure that the entire the bottom of the chamber is located on the cold plate.

Experimental Method

3. Pour hot water of about 140°F into the aluminum cup on top. About two thirds full will be enough.

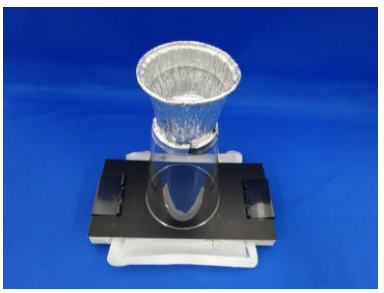


Pour hot water of about 140 degrees Fahrenheit into the aluminum cup attached to the top of the chamber. You can use hot water, but be careful not to burn yourself.

It will suffice if the hot water fills about two thirds of the cup.

Experimental Method

4. Observe the area around the bottom of the cloud chamber while shining a flashlight from the side.
   * When it starts to look as if a fine rain is falling, you are almost there. Look all over the bottom and look for a whitish contrail-like track!



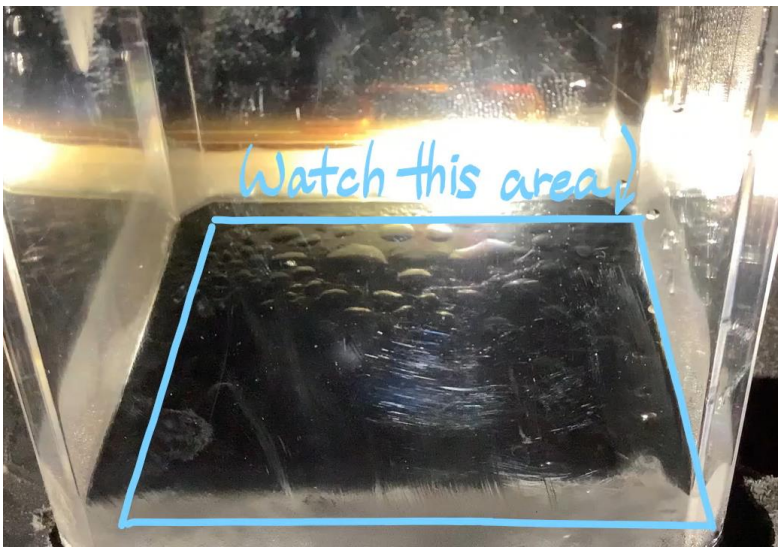
Place the flashlight almost horizontally near the bottom of the chamber and check the internal space. If you see a fine rain falling inside, it's a sign that the chamber has begun to prepare to show tracks.

Wait for few minutes, and search from various angles for tracks.

To find radiation tracks, adjust the angle of the light while looking at the bottom of the chamber. As long as the angle allows you to see rain falling, there is a high possibility that you can observe the tracks as they are. The tracks begin to show about few minutes after the start of the experiment and can be observed for about 20 minutes.

Some tracks stay longer and others shorter, but all disappear in about a second or two. If you want to take pictures, we recommend you videos rather than photograph.

How you will see the tracks



This is how you will see the tracks. I used square plastic box for a better view in video.

This video is taken with flashlight at the furthest side from the camera, facing this way. You might find more

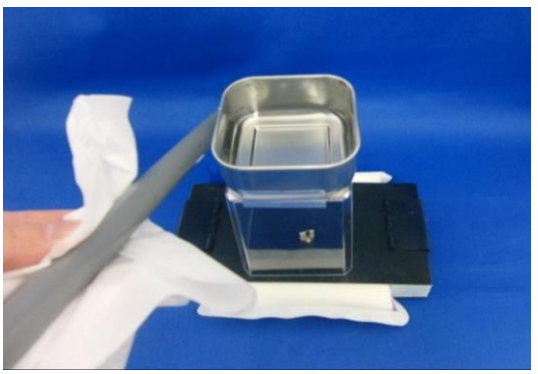
Please watch the bottom area, and you will eventually see white places where it’s actually a line of small ethanol droplets in a line.

You can see some tracks are thick and easy to see, while others are thin. Over time you will get used to watching and spotting tracks.

A Tip for Making Tracks More Visible

When radiation and cosmic rays collide with air molecules, they produce ions, and around them, ethanol aggregates, producing a track-like appearance.

You can remove unnecessary ions by placing a static stick close to the cloud chamber from outside.



There are several tips for making tracks more visible.

There might be times when the tracks become less visible as you continue the experiment.

This is because the cloud chamber is designed observe ethanol droplets, which are made by ions from radiation and cosmic rays colliding with air particles. When there are many ions in the air in the chamber, it is difficult for ethanol to aggregate around the NEWLY produced ions – because since there are already so much ions in the air they won't make much difference - , and eventually it becomes difficult to see the tracks.

In such cases, you can remove the ions in the air by static electricity, and then you can see the tracks again clearly. For example, rub a vinyl chloride rod with tissue paper to create static electricity and place it close to the wall of the chamber. Then, ions can be removed and tracks will be easier to see. Try this when you cannot clearly see the tracks.

Please try this at your school, and wow your students with beautiful tracks! The procedure is all on the handout I put in Google Drive earlier. If there is something wrong with the cloud chamber, or something you don't understand, please contact me and I'll do my best to help you succeed.

That’s all for today’s presentation! Thank you!

References

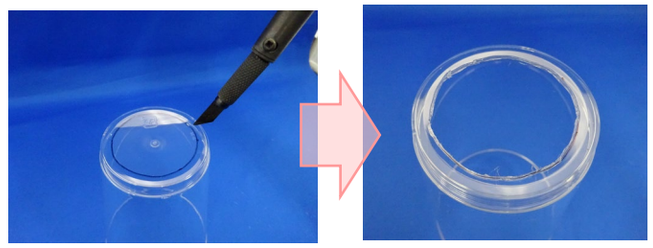
- Side Reader on Radiation, Ministry of Education, Culture, Sports, Science and Technology (Oct. 28, 2021) https://www.mext.go.jp/b_menu/shuppan/sonota/attach/1409776.htm
- Simple cloud chambers using a freezing mixture of ice and cooking salt, Kyohei Yoshinaga/Miki Kubota/Masahiro Kamata, Physics Education, pp23-27, 2015
- Simple cloud chambers using gel ice packs, Masahiro Kamata/Miki Kubota, Physics Education, pp429-433
- Japanese Internet System for Calculation of Aviation Route Doses (Jan. 20, 2022) http://www.jiscard.jp/index.shtml

Build your own Cloud Chamber

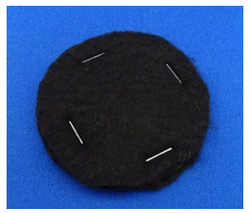
[Cloud Chamber]

Things you need
1 plastic cup (clear, hard one of about14oz. one with no designs or wavy sides!).
1 Aluminum cup (bottom size same as the bottom of plastic cup)
3 Black felt circles, cut in the same size as the bottom of the cup
Aluminum tape

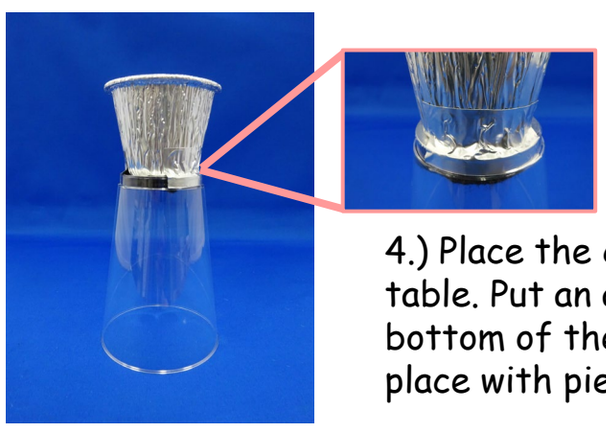
1.) Remove the bottom of the plastic cup with a hot knife. A hot rod used for soldering can also be used for this process.



2.) Cover the hole in the bottom of the plastic cup with some aluminum tape. Seal it from the outside so the sticky side of the tape will be inside of the cup!



3.) Stick three felt circles (staple them together so they won't fall apart!) onto the aluminum tape at the bottom of the cup. Press firmly to secure it in place.



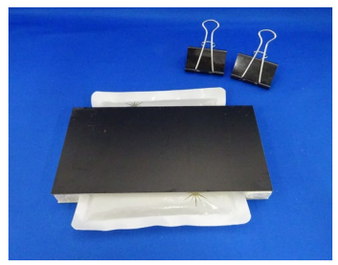
4.) Place the cup upside down on the table. Put an aluminum cup on the bottom of the cup, and secure in place with pieces of aluminum tape.

[Cold Plate]

Things you need
2 aluminum plates
(about 7.8in x 3.9in, 0.6in thick)
*needs to be black at least on one side
2 Styrofoam blocks (0.8in x 1in x 4in)
2 double clips, each 2inches wide
1 ice pack "Frozen Sheet -18°C"
*or, any gel ice pack that keeps around 0°F

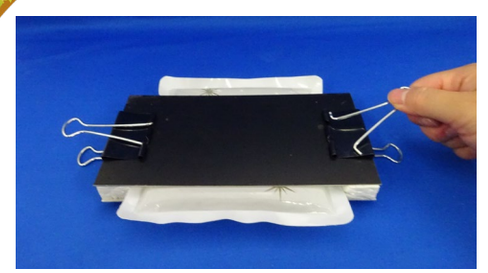
[1] Put one aluminum plate on the table, black side facing down. Peel off the release liner on the Styrofoam blocks and place them in both sides of the plate.

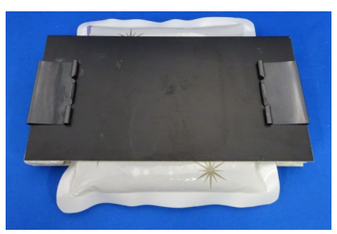
[2] Place the ice pack between the Styrofoam blocks. (Ice pack should NOT be frozen at this point)



[3] Put another aluminum plate on top, black side facing outward. The whole thing will look like "Styrofoam and ice pack sandwiched by two black plates".

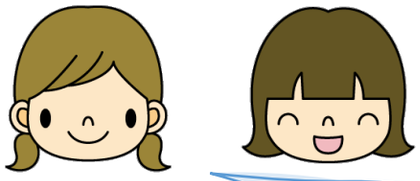
[4] Secure things in place by clamping the shorter sides with double clips. Remove the handles of the clip.





Leave it in a freezer for a day and there you have it - a COLD PLATE!

Experimental procedure



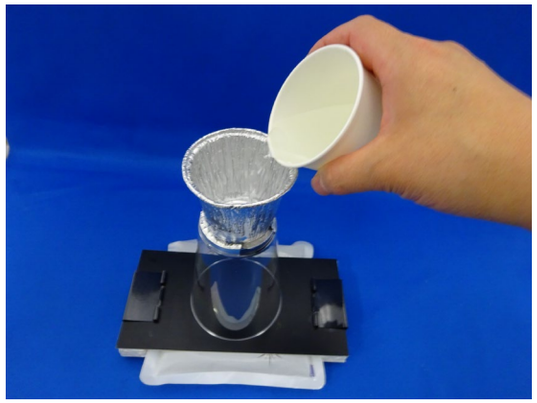
Before the experiment….
freeze the cold plate, and prepare some hot water!

1.) Turn the cloud chamber upside down and soak the black felt part with about 6mL of ethanol.

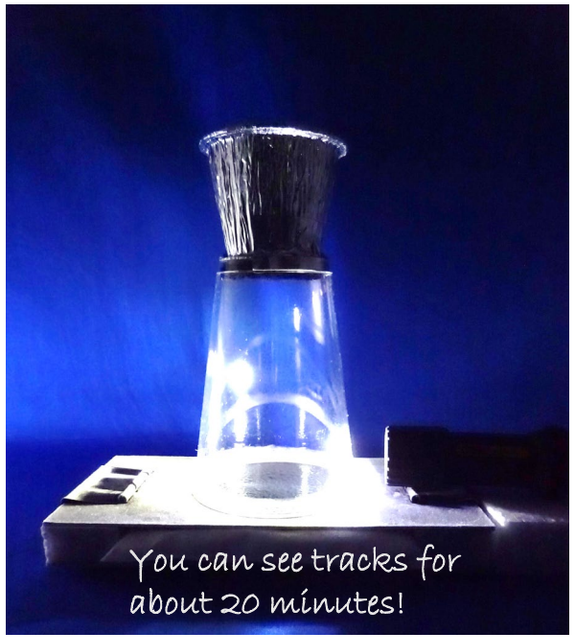
Ethanol concentration should be 70% or more. Absolute alcohol is the best!

2.) Take the cold plate out of the freezer. Place the cloud chamber at the center of the cold plate with its aluminum cup facing upward.

3.) Pour hot water of about 140°F into the aluminum cup on top. Hot water about 2/3 full will be enough.



4.) Make the room dark, and observe the area around the bottom of the cloud chamber while shining a flashlight from the side.



the tracks appear near the bottom of the cloud chamber. Watch the falling ethanol rain until you start to see some whitish places where ethanol falls in some kind of a cluster.

Watch how the tracks appear on video!

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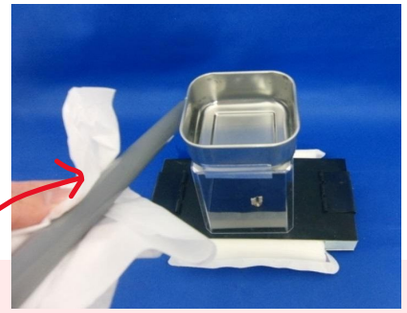
A TIP for making tracks more VISIBLE

You can remove unnecessary ions in the air (that prevents the tracks from showing clearly) by placing something charged with electricity close to the cloud chamber!



For example,
a Vinyl Chloride stick rubbed with Kleenex

You can also get similar cloud chambers from below:

Cloud Chamber (Cold Plate Type)
from Arbor Scientific
https://www.arborsci.com/